MAGNETIC FIELD TRAPPING IN HIGH-T_c SUPERCONDUCTORS

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We are studying the trapped magnetic field, B_t, in high-temperature superconductors (HTSC). At IUCF we study the improvement of B_t achieved by radiation-induced pinning centers. We have studied radiation-induced pinning centers using $^1H^+$, $^3He^{++}$ and $^4He^{++}$ bombardment at IUCF, and using thermal neutrons at the Texas A&M reactor in the reaction $n_t^0 + {}^{235}U \rightarrow f + f'$.

We define R to be the ratio of the trapped field before irradiation to the trapped field after irradiation. For high-energy charged-particle bombardment we find:

$$R = 1 + \Delta R_{max}(1 - e^{-F/F_0})$$

where $F_0 \approx 6 \times 10^{15}$ p^+/cm^2 or 2.1×10^{15} He^{++}/cm^2. Fig. 1 shows the trapped field in a tile of HTSC before and after p^+ bombardment. Fig. 2 is an example of Eq. 1 applied to a $^3He^{++}$ run done at IUCF.

The trapped field is given by:

$$B_{t,max} \propto J_c f(d)$$

where J_c is the critical current, d is the diameter of a current-carrying grain (quasi-crystal), and $f(d)$ is a monotonically increasing function of d. J_c increases with the number and quality of pinning centers, and also increases with decreasing temperature. During the past year, we did a systematic study of how J_c depends on temperature. Using this and the expression for $B_{t,max}$, we found a simple phenomenological law[4] valid in the region 20≤T≤65 °K:

$$B(T_2) = B(T_1)\left[\frac{93° - T_1}{93° - T_2}\right]^2$$

We had previously studied B_t at 77 °K and, by pumping on the liquid nitrogen, at 65 °K. We found:

$$B_t(65\ °K) = 2.6 B_t(77\ °K)$$

Thus a magnet made of the processed materials will trap eighteen times as much field at 20 °K as at 77 °K.

We used a set of 8 tiles which had been bombarded at IUCF to construct a mini-magnet. The tiles were composed of $Y_{1.4}Ba_2Cu_3O_7$, and were a mixture of $^1H^+$ and $^3He^{++}$ bombardment products. This magnet set a record for field trapped at 77 °K, $B_t = 1.52$ T (Ref. 2). The results are shown in Fig. 3.

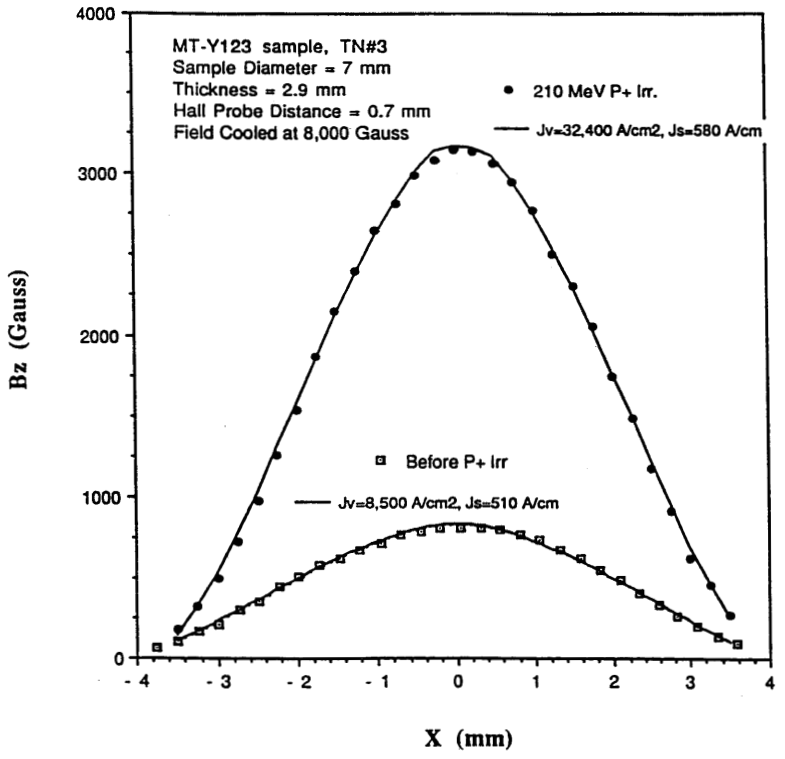

Figure 1. Mapping of magnetic field vs. position on a tile of HTSC, before and after irradiation with $^{1}H^{+}$ at 200 MeV at IUCF.

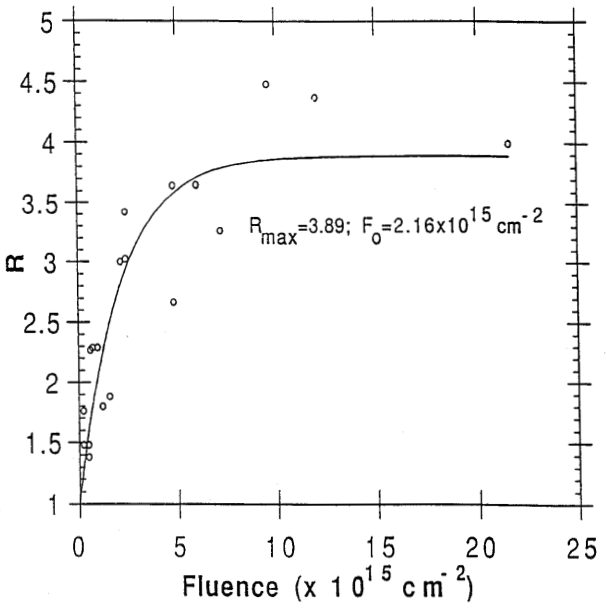

Figure 2. Plot of R vs. fluence for $^{4}He^{++}$ bombardment. The data were taken at IUCF.

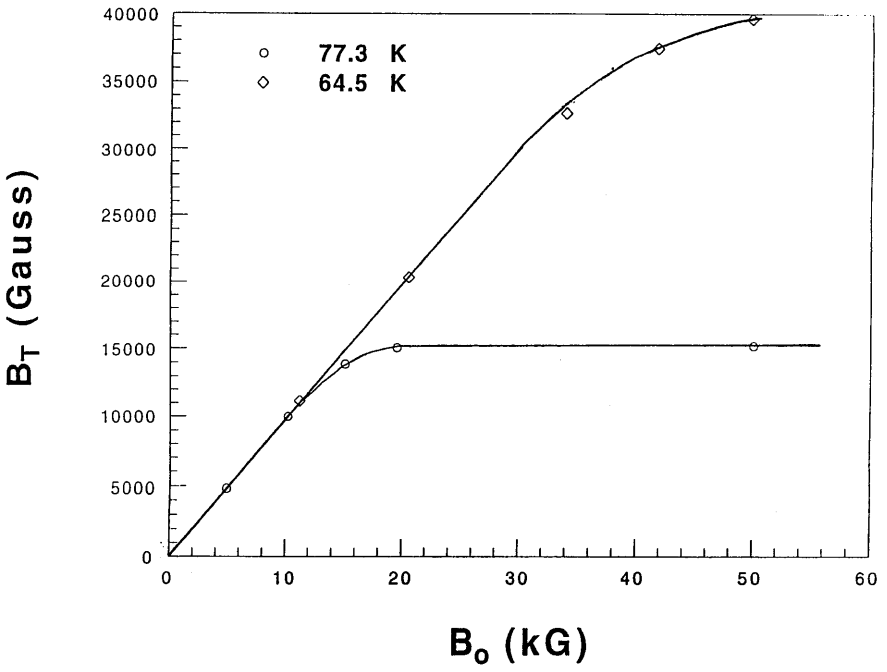

Figure 3. Trapped field at 77 °K and 65 °K. At each point the warm mini-magnet is placed in the activation field, B_A. After cooling, the magnet traps a field B_t.

During the past year we obtained and refurbished a low-T_c superconducting *activation* magnet capable of 10.7 T fields. We are also building, but have not yet commissioned, a cryostat to achieve constant T in the range $10 \leq T \leq 77$ °K. In lieu of the cryostat, we again pumped on the liquid nitrogen to obtain 65 °K. Using the high-field activation magnet, we achieved a stable trapped field of ~4 T (Ref. 3, see also Fig. 3) on the 8 tile magnet processed at IUCF.

The previous record for a permanent field for any bulk material at any temperature was set at Stanford University in 1976, and was 2.3 T at 4.3 °K. This 17-year-old record has now been surpassed.

We continue work to increase J_c, and increase d. To date, both have been doubled compared to the materials in the record magnet.[6] However, even the old materials have excellent potential. The expression for the maximum trapped field indicates that the record magnet (4 T at 65 °K) will trap ~27 T at 20 °K. Before reaching this field, we expect the tiles to crack under B^2 pressure. We will study this cracking in the near future, and methods to prevent it.

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